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MICROCOMPUTER AIDED TRACKING (MCAT)(U) NAVAL RESEARCH
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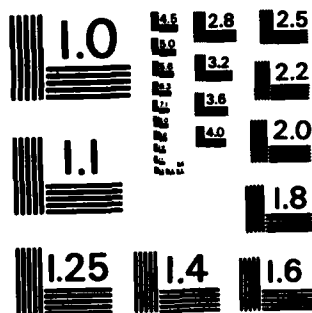
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MICROCOMPUTER AIDED TRACKING (MCAT)

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BACKGROUND

The MCAT (Microcomputer Aided Tracking) project began in FY 1977 as part of the Radar/Reliability Performance Improvement (RR/PI) Program under NAVSEA 62X sponsorship. The objective of the RR/PI program was to investigate shipboard radar problems and to provide short/medium term low-cost improvements in these problem areas. This effort included examining equipment associated with radar systems such as displays and switchboards. The specific objective which led to MCAT was to improve performance of radar indicators and to improve radar operator performance. The RR/PI program funded MCAT through FY 1980. In FY 1981, MCAT received further funding under the Surveillance Block Funds for work on the detection hardware and from the NAVSEA 62X Radar Display and Distribution System (RADDS) program. The RADDS program has as one of its objectives to replace the current SPA-25/66 with a universal display designated the SPA-25(XX). This display has as a growth option the inclusion of the MCAT concept and other features that grew out of the MCAT concept. The goal of the MCAT project was to investigate the effectiveness of operator initiated tracks followed by automatic tracking. Adding this capability to a display was intended to relieve operator overload and fatigue which results when the operator is limited to grease pencil tracking. MCAT combines several microprocessors and a microcomputer-driven PPI with graphics capability. The operator is required to make the initial detection and MCAT then performs automatic detection and tracking in a limited area centered around the detection. This approach was chosen because it is far less costly than a full-up auto detect and track approach.

MCAT is intended for use in a non-NTDS (Naval Tactical Data System) environment where operator aids are minimal at best. There are approximately 200 non-NTDS ships in today's Navy. Each of these ships has a combat information center (CIC) which includes numerous PPIs typically SPA-25s, SPA-66s, SPA-50s) and various manual means (e.g., air summary plotboards, NC-2 plotters) of producing summary plots and performing calculations (e.g., maneuvering board paper) pertinent to tracks in progress. The operator's duties are time-consuming and there are many things that could be done via computer control and graphics displays that the non-NTDS operator must now do manually. Because there is much manual information handling, accumulation of data is slow and there is a large probability of error. Typically, a non-NTDS operator sits in front of a PPI in a darkened room watching for detections. When he or she sees a detection of interest, he makes a grease mark on the scope face over the spot where the detection was seen. He does this on sweep after sweep building a picture of the tracks he is watching. If he wishes to know any details concerning the motion of his tracks relative to his own ship (course, speed, closest point of approach), he must do the calculations manually. He also reads off the coordinates of his tracks over sound power phones, as one of several inputs, for someone to plot as a summary picture.

For a non-NTDS operator to do a good job he or she must be alert and quick so that he can keep an accurate grease pencil track on all the detections and spot new detections as they occur. Experience has shown that he can do this for 4 or 5 targets for as long as 20 or 30 min, but in reality, he must stand watches of 2 to 4 h. This means that early in his watch fatigue has already set in, and if the number of tracks exceeds 4 or 5 targets, there simply is not time for him to maintain tracks. Even if

he could, there is no time to notice and respond to new detections. In other words, tracking and detection are incompatible and long watches negate good performance. Obviously, a solution to these problems is to automate some of the detection and tracking functions with the MCAT system.

SYSTEM CONCEPT AND IMPLEMENTATION

MCAT was based on six original assumptions/goals:

1. Accept data from one radar at a time
2. Tailor the MCAT system to the gross parameters describing a particular radar (beamwidth, PRF, RPM)
3. Require manual initial detection
4. Provide automatic tracking of operator-detected targets in the clear
5. Alert the operator to resolve difficult decision situations such as fades and crossing tracks
6. Have the computer maintain tracks, tags, and histories of required targets.

Figure 1 shows the main building blocks of the MCAT system, and Fig. 2 is a photo of the system. The display is a standard UYQ-23 display built by the Motorola Corporation. It consists of a microcomputer called the MARC-16 and a display controller. The MARC-16 is the heart of the MCAT system. Here the track files are maintained and track filtering occurs. The MARC-16 also prepares the data for the display controller to display. The MARC-16 has a 16-bit word and a 1.5- μ s cycle time. The MARC-16 and the display processor have simultaneous access to a 16K-word memory. The detection and association hardware, built by NRL, receives raw video from the radar switchboard. It buffers and supplies the raw video to the UYQ-23 and also processes the video for the detection and association phase. A PDP-11/03 serves as an interface between the UYQ-23 and the detection and association hardware, and is also the means for loading the software initially into the UYQ-23.

The operator interface consists of i. a stiffstick or track ball that is used to move a special symbol (the principal designator) around the display; ii. a standard keyboard for inputting alphanumeric character strings; and iii. a bank of 40 programmable function buttons that form the basis of the operator interface. Any action the operator wishes to invoke is accomplished via one of these 40 function buttons.

MCAT provides the operator with two ways of initiating a track. Either he or she knows where the detection is because he has seen it or he knows where he expects to see a detection. In either case, he positions the principal designator to the center of the area of interest and pushes the appropriate function button for establishing a new track. A tracking correlation window (range/azimuth sector) is now assigned, centered around the location of the principal designator. The operator has a choice of three window sizes that are intended to handle three general velocity classes. For convenience, these are labeled missile, air, and surface. The operator also has the capability of redefining the size and shape of any or all of these basic windows. A total of 32 tracks can be initiated in this manner.

The center of the tracking correlation window is moved based on the predictions of the track filters [1]. The movement appears smooth to the operator because the predictions are interpolated 5 times/s between radar sweeps. The following equations govern the predicted range and azimuth

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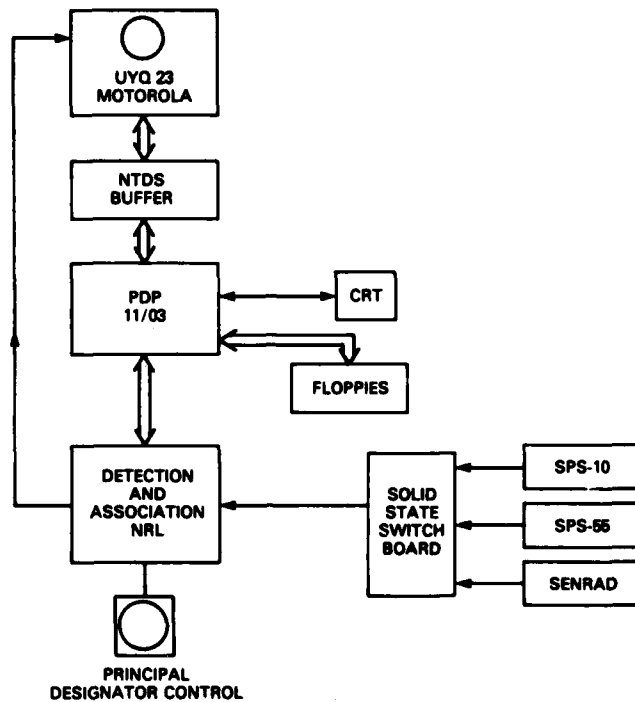


Fig. 1 — MCAT system building blocks

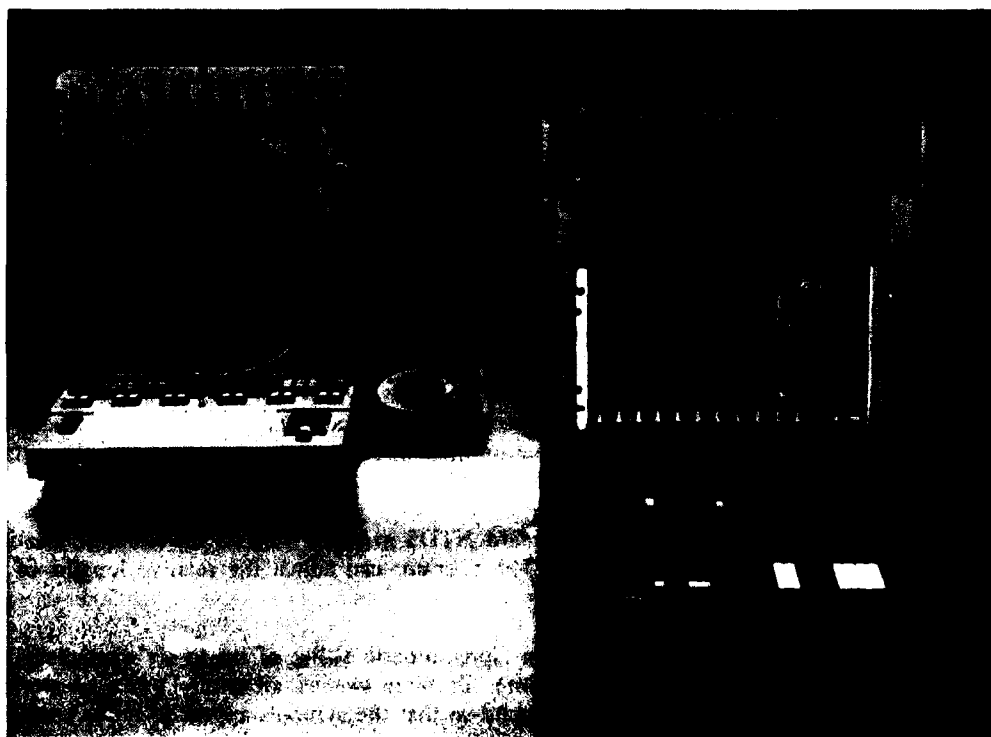


Fig. 2 — MCAT system console

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positions and velocities, where R is range, A is azimuth, m is measured position, pr is predicted position, sm is smoothed position, vsm is smoothed velocity, and vpr is predicted velocity:

$$\begin{aligned}R_{sm} &= R_{pr} + \alpha(R_m - R_{pr}) \\R_{vsm} &= R_{vpr} + \beta(R_m - R_{pr}) \\R_{pr} &= R_{sm} + R_{vsm} \\R_{vpr} &= R_{vsm} \\A_{sm} &= A_{pr} + \alpha(A_m - A_{pr}) \\A_{vsm} &= A_{vpr} + \beta(A_m - A_{pr}) \\A_{pr} &= A_{sm} + A_{vsm} \\A_{vpr} &= A_{vsm}\end{aligned}$$

where $\alpha = (4N - 2)/(N^2 + N)$, $\beta = 6/(N^2 + N)$ and $N = \eta \times \text{bandwidth}$. The factor η is the number of data points (i.e., history points) incorporated into the track, and the bandwidth is operator selectable, varying from wide to narrow on a scale of one to nine. The window size and tracking bandwidth adjust automatically and independently in range and azimuth depending on the type of target (surface, air, missile) and the quality of prediction. Each type of target has a basic acquisition window size associated with it, for example:

	Range (nmi)	Az (deg)
Surface	0.625	7.6
Air	2.5	8.44
Missile	5.0	11.25

The window-shrinking sizes are $\times 1$, $\times 3/4$, $\times 1/2$, or $\times 1/4$ of the basic acquisition sizes. (Minimum allowable window azimuth is $2.5 \times \text{beamwidth}$.) The filter error (i.e., measured minus predicted) is examined for being within $1/8$ of one of the window sizes. If it is, the window shrinks (or expands) to that size. Once the shrink size is determined, a corresponding η for the α and β calculation is also chosen.

Velocity is measured in two ways. For slow moving targets (surface) the noise component of the velocity vector tends to dominate and distort the velocity. To reduce this effect, the velocity of surface targets is measured as a straight line over approximately 180 s. For faster targets (air, missile) the velocity is filtered over a variable number of sweeps depending on the quality of the prediction. The better the prediction, the more sweeps are included in the filtering process.

Tracks are coasted through fades, and the graphics symbols associated with the track flash for the duration of the fade. The operator can select the number of scans (one through nine) through which coasting persists after which the track is automatically dropped out of the system.

Tracks are indicated on the scope by standard NTDS symbols (unknown, friendly, hostile, air, surface, missile) and each has a speed leader. The operator can adjust the relative lengths of all the speed leaders.

The operator can label each target with an alphanumeric string of up to six characters. These labels can be suppressed and redisplayed at any time. Between sweeps, all symbol positions are interpolated and symbols are redisplayed five times a second so that the symbols appear to move continuously between sweeps.

The track history of all targets or any subset of the targets may be displayed. A track history is displayed as a series of asterisks (*) showing the location of the target at nine discrete points in the past. For surface targets the history displayed is over approximately 180 s so that each point is separated by 20 s backward in time. For air and missile targets, the history displayed is over the last nine radar scans. That is, for a 15-rpm radar, the history of an air or missile target is over 40 s (the current position plus 36 s of history). Figure 3 shows a typical MCAT PPI presentation showing two simulated target tracks. The targets' positions are marked with standard NTDS symbols and operator-generated labels. The target labeled F-14 is "hooked." Current estimates of the range, bearing course, and speed of that target are shown in the box labeled hooked. The dots trailing behind the target symbols are track histories, and the small vectors emanating from the center of the target symbol are graphic indications of target speed. The vector pointing toward the MIG 23 is a cursor. The length, direction, and origin of the cursor are shown in the cursor box.

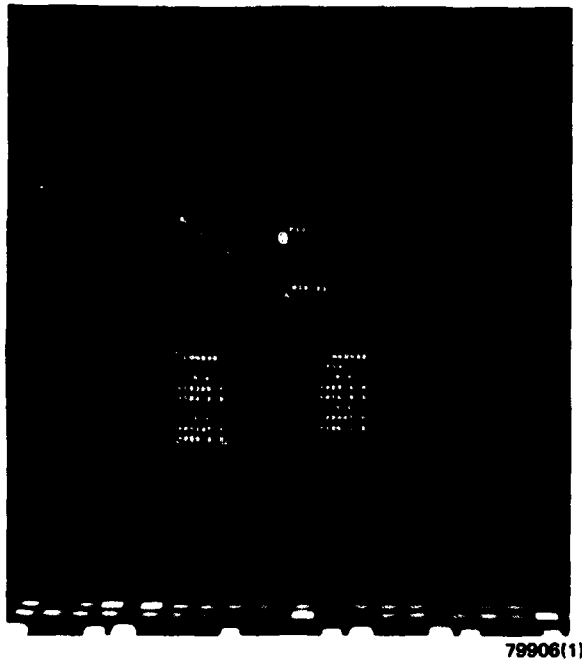


Fig. 3 — MCAT PPI display

Figure 4 illustrates the three information readouts that can be displayed in addition to the PPI presentation and tracking graphics. Figure 4a shows the operator assigned label; tracking hardware device number; and current estimated position, course and speed of a target of interest. Figure 4b gives the current position of the principal designator, and Fig. 4c gives the range and bearing of the cursor and the position of the cursor origin.

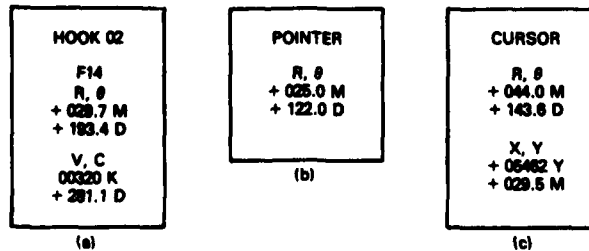


Fig. 4 — MCAT information readouts

Also, an electronic plotting aid (EPA) that functions as an electronic grease pencil is available. The operator moves the principal designator to a detection and invokes the "plot" function. A special symbol (+) is displayed at the coordinates of the principal designator and the time-of-day, corrected to the most recent time the sweep passed this position, is recorded in the UYQ-23 memory. The operator can "plot" all the detections he or she desires, limited to the available memory. When the available memory has been used, any new "plot" occupies the memory previously assigned to the oldest "plot" in the system and that "plot" is no longer available and, therefore, no longer displayed or remembered. At a later time the operator can request the velocity between any two of the "plots" in the memory and this is displayed along with the course between these two points. The EPA feature also allows the operator to request a line to be drawn anywhere that he positions the cursor. Thus, the operator can build up a designation of such things as clutter areas and coast lines.

The RPM of the selected radar is automatically measured by the software. Other parameters can be specified by the operator using the keyboard as the input mechanism. He or she can select the radar and input the radar's beamwidth. He can specify the tracking filter bandwidth from wide to narrow on a scale of one to nine and the number of scans (one through nine) required before automatically dropping a track. Finally, he can select the number of reference noise cells (4, 8, or 16) to be used in the "greatest of" constant false alarm rate (CFAR) detection scheme.

A block diagram of the track association and centroiding hardware is shown in Fig. 5. The detection process utilizes standard automatic detection and tracking (ADT) signal processing consisting of a two-stage integration technique [2]. The first stage is a "greatest of" cell-averaging CFAR (Fig. 6) circuit that integrates the video and raises or lowers the threshold as the average value varies. This minimizes the effects of noise and clutter in the range dimension. Signals that exceed this threshold are further tested in Stage II with an azimuth staircase integration circuit [2] (Fig. 7) to minimize the effects of noise and clutter in the azimuth dimension. Figure 6 is a generalized diagram of the "greatest of" cell-averaging CFAR process. An operator-selectable number of noise reference cells on either side of a range cell of interest is averaged and the larger is chosen and scaled for thresholding. This is compared to the range cell of interest and either a target is declared or not. This entire process is repeated on a range cell by range cell basis. The second stage of the ADT process is represented in Fig. 7. This is a counting scheme that adds 3 to a counter each time a detection is declared via the Stage I process or subtracts 1 each time no detection is declared until the counter reaches a value that is a function of the number of radar pulses per beamwidth. The counter is never allowed to exceed this value. At this time, the beginning of detection is declared and the range and azimuth of the beginning of detection is stored in a RAM. The process is then reversed, subtracting 3 from the counter when no detection is declared and adding 1 if a detection is declared, until the counter reaches zero. Again the counter is limited and not allowed to decrement past zero. At this time, end of detection is declared and the range and azimuth of the end of detection are stored in memory. The Stage II processing is performed at each PRF on a range cell by range cell basis.

Once the initial detection has been accomplished (usually by the operator moving the principal designator symbol to the video and initiating the track), the target is "known" to exist in a relatively small range and azimuth sector and the association only needs to be done in this small sector. The beginnings and ends of detections occurring in this sector are stored in a 256 word RAM. The detections are then sorted and centroided using an INTEL 8748 microprocessor. The INTEL 8748 is a simple, inexpensive microprocessor with an 8-bit word and a $2.5 \mu\text{s}$ cycle time. It makes sense to use such a microprocessor because the sorting and centroiding is not a time-critical process. There is a whole scan in which to process the data. The microprocessor reports the detection closest to the predicted point as the new measured target position and also reports back an assessment of the presence of clutter.

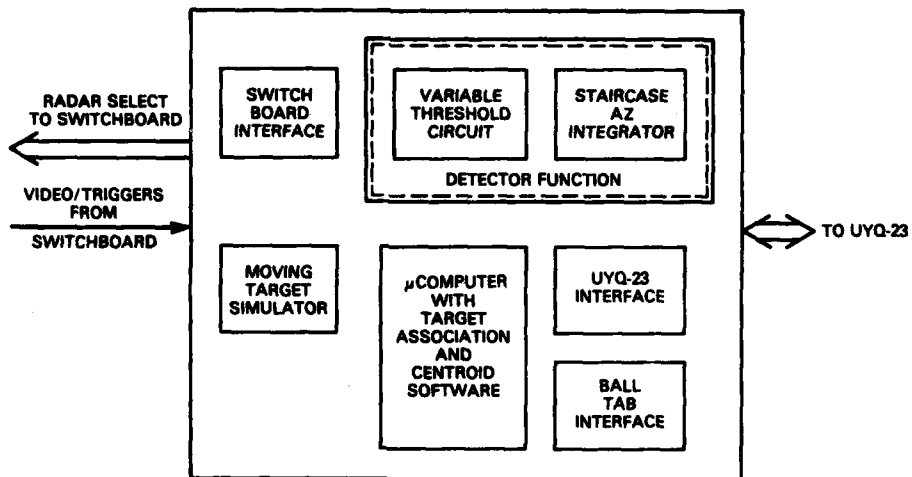


Fig. 5 -- Track association and centroiding hardware

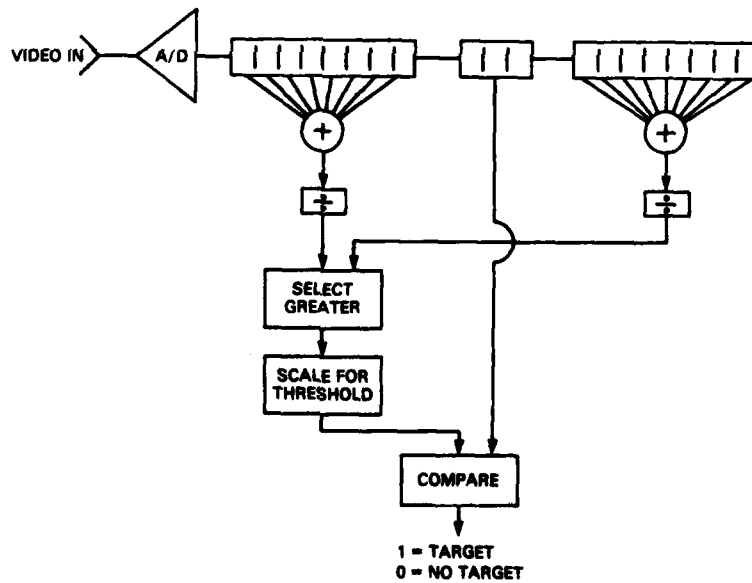
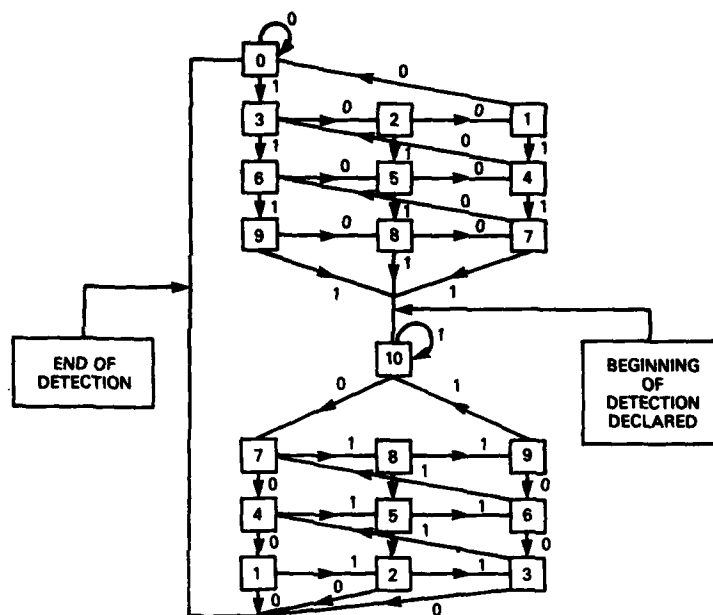


Fig. 6 -- Detection: Stage I "greatest of" cell-averaging CFAR



EX: 8 PULSES/BEAMWIDTH

Fig. 7 — Detection: Stage II azimuth staircase integration

Figure 8 is a diagram showing the program logic states in the MARC-16 that govern a track or potential track. There are 32 available tracking channels. Each sweep, the detection/association hardware reports back one of five possible codes: no targets, one target, two targets without doubt, two targets with doubt, or clutter (more than two targets). To determine doubt or no doubt when two targets are present, the tracking window is thought of as being divided into 16 cells (4 range divisions and 4 azimuth divisions.) Further, the center four cells constitute the center of the window. If both targets appear in the center of the window, then the report back is of two targets with doubt. If one is in the center and the other is not, then the report back is of two targets, no doubt. A channel is in the deactive state until the initial detection occurs, at which time the channel enters the active looking state. If a single detection is reported back on the next sweep, the channel transitions to the acquisition state. If a single detection occurs on the following sweep the channel remains once more in the acquisition state. A single detection at this point transitions it to the tracking state where it will remain as long as one target or two targets with no doubt are reported back. If such is not the case, it transitions to a coast state and all graphics symbols associated with the track flash to indicate trouble to the operator. A report of one target or two targets with no doubt will transition it back to track or, if it remains in trouble for the operator selected number of scans for a trouble track, it will automatically drop out of the system. On the same basis, a tracking channel can also drop out of the system while in the active looking or acquisition state.

CONCLUSIONS

The moving target simulator was built and used solely to facilitate debugging of the MCAT system since the target movements were controllable, predictable, and repeatable. The system was assessed using targets of opportunity and surface surveillance and air surveillance radars. The MCAT concept turns out to be quite practical. It does indeed automatically track targets in the clear, leaving the operator free to watch for further detections, thus easing the job of the non-NTDS operator. The

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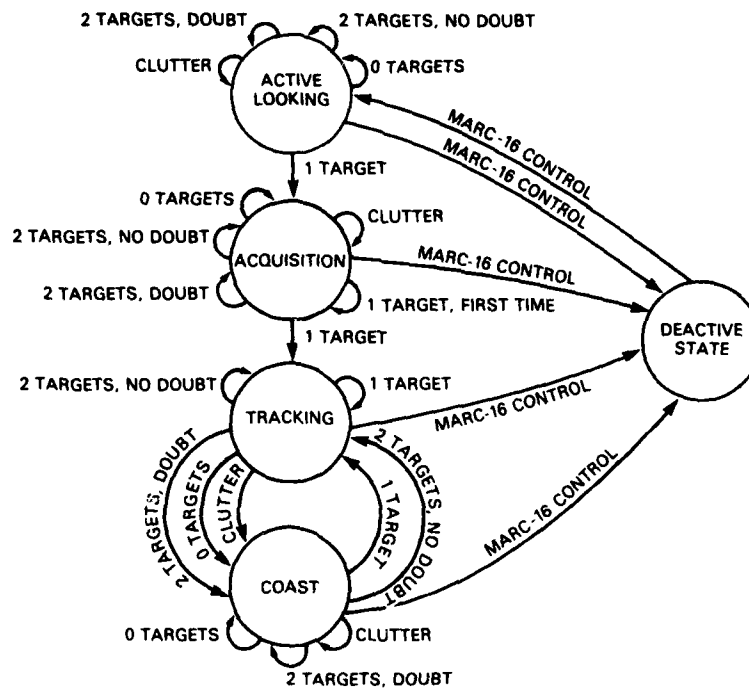


Fig. 8 — Program logic states in the MARC-16

problem areas remaining are in the detection and centroiding process. These problems, however, are present in any ADT system and are not viewed as a weakness in the MCAT concept itself. The EPA feature provides a decided improvement over the reflection plotter. When the display is offset or expanded, the electronic grease marks move appropriately without the necessity of being redrawn. Also, the automatic velocity calculation feature saves the operator a lot of time and trouble when he or she needs to know the target's velocity. As an experiment, the velocity calculation capability of a SPA-25 operator was compared against the EPA calculation and the MCAT calculation. All three velocities compared favorably but a lot of effort on the part of the SPA-25 operator is required. He has to first record the beginning and ending time of his observations. Then since he has no offset capability on his scope, he has to measure the length of the vector between his beginning and ending points and then compare it to his range ring scales to find out what the actual distance is. If he is careful, he can get a reasonable measurement, but it is a time-consuming process. If he had been using EPA he need only have moved his principal designator to the beginning and ending points and have pushed the velocity function button at each of these points. On pushing velocity the second time, he would have gotten an immediate readout of the velocity and the course of the target. If he had had the target in track using MCAT, he need only have moved his principal designator to the target and then have pushed the "hook" function button. He would then have gotten the position of the target and its course and speed (Fig. 3).

It is not hard to imagine that the MCAT concept could be further extended to handle far more operator activities such as CPA calculations, air intercept calculations, and designation to a weapon system. It also could be made to accept additional inputs such as sonar, geographical points, intelligent targets, and/or an external graphics source.

The addition of any or all of these features would enhance the MCAT capability of aiding the non-NTDS operator to do a better job of tracking with more efficiency and accuracy.

ACKNOWLEDGMENT

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